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Site Description, Operational History, and Broadband Noise Characteristics of IRIS/IDA Stations AAK (Ala-Archa, Kirghizia) and TLY (Talaya, Lake Baikal Region, Russia)

January 10, 1992
Semi-Annual Technical Report

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Averaged ambient ground noise power spectra are calculated for two broadband IRIS/IDA seismic stations deployed at Talaya (TLY) near Lake Baikal in Russia and Ala-Archa (AAK) near Bishkek in Kirghizia, central Asia. Site descriptions are provided for these stations, as well as major episodes up to mid-1991 in their operational history that are relevant to potential data users. Findings can be summarized as follows: AAK shows among the lowest average absolute nighttime noise levels above 1 Hz documented to date for IRIS/IDA stations in the former USSR; its night-averaged noise levels above 1 Hz are very similar to those observed at GAR. Ground noise increases during the day at AAK, with the maximum increase (7-9 dB) occurring between 2-3 Hz. Below .7 Hz, day and night noise at AAK is the same. TLY average nighttime noise levels are about 6-10 dB higher than AAK levels above 1 Hz; its night-averaged noise above 1 Hz is very similar to that observed at IRIS/IDA station KIV. Below .6 Hz, nighttime levels at AAK and TLY are comparable, except that TLY has lower horizontal noise levels (4-5 dB) at periods longer than 25 s. Almost no difference between night and day noise was observed at TLY; in this sense it is unique among IRIS/IDA stations in the USSR. Microseism peaks at both stations are comparable (between -135 to -140 dB relative to $(1\ m/s^2)^2/Hz$). High-frequency noise levels appear to be fairly constant between 10 - 50 Hz, at between -150 to -140 dB relative to $(1\ m/s^2)^2/Hz$.

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Abstract

Averaged ambient ground noise power spectra are found two broadband IRIS/IDA seismic stations deployed at Talaya (TLY) near Lake Baikal in Russia and Ala-Archa (AAK) near Bishkek in Kirghizia, central Asia. Site descriptions are also provided for these two stations, as well as major episodes up to mid-1991 in their operational history that are relevant to potential data users. Findings can be summarized as follows: AAK shows among the lowest average absolute nighttime noise levels above 1 Hz documented to date for IRIS/IDA stations in the former USSR; its night-averaged noise levels above 1 Hz are very similar to those observed at GAR. Ground noise increases during the day over night levels at AAK, with the maximum increase (7-9 dB) occurring between 2-3 Hz. Below .7 Hz, day and night noise levels are the same at AAK. TLY average nighttime ground noise levels are about 6-10 dB higher than AAK levels above 1 Hz; its night-averaged noise levels above 1 Hz are very similar to those observed at IRIS/IDA station KIV. Below .6 Hz, nighttime levels at AAK and TLY are comparable, except that TLY has lower horizontal noise levels (4-5 dB) at periods longer than 25 s. Almost no difference between night and day noise levels was observed at TLY; in this sense it is unique among the IRIS/IDA broadband stations in the USSR. Microseism peaks at both stations are comparable (between -135 to -140 dB relative to $(1\ m/s^2)^2/Hz$) at both stations. High-frequency noise levels appear to be fairly constant between 10 - 50 Hz, at between -150 to -140 dB relative to $(1\ m/s^2)^2/Hz$.

1. Introduction

In 1988, Project IDA at Scripps Institution of Oceanography began installing broadband seismic stations inside the borders of the former USSR in a Joint Seismic Program between the Soviet Academy of Sciences, the Incorporated Research Institutions for Seismology (IRIS), and the United States Geological Survey. The intent of these stations, in widest terms, is to broaden the coverage of the global digital seismic network. However, state-of-the-art seismological stations inside Russia and the former republics of the USSR can address many questions relative to nuclear monitoring For example, studies have been done regarding the station coverage necessary on a regional scale to monitor a threshold limitation agreement below the current threshold limit of 150 kilotons. Before the existence of 'in-country' seismic stations, such studies had to assume certain characteristics about the geophysical properties of Eurasia, such as the level of ambient Earth noise, or the attenuation of regional seismic phases. After several years of data collection, many of these assumptions can now be replaced with observations. The applicability of many proposed regional monitoring tools that have been developed with DARPA funding, such as discrimination between nuclear and non-nuclear seismic sources, or yield estimation of the explosive source from seismic phases, can be tested directly on the Eurasian continent with the new IRIS/IDA data.

The stations inside the former Soviet territory are part of a global network operated and maintained by Project IDA. There are currently 13 operational broadband IRIS/IDA stations which deploy the Streckeisen STS-1 very-broadband seismometer; six of these are in the former Soviet Union (Figure 1). In this report, we refer to these as JSP stations, where 'JSP' refers to station installed under the Joint Seismic Program. Work on this contract focuses on the characterization of noise levels at IRIS/IDA JSP stations and evaluation of network performance and network capability. In this report, we present results regarding noise power spectra and the operational history of two IRIS/IDA JSP stations in Ala-Archa, Kirghizia (AAK), and Talaya, in Siberia near Lake Baikal (TLY), that were installed in October 1990.

2. Overview of Equipment at IRIS/IDA JSP Sites

The Steckeisen STS-1 very broadband seismometer has a basic response that is flat to ground velocity between 2.7 mHz and 10 Hz (Figure 2). The IDA MK4 and MK6a data acquisition systems (DAS), currently deployed at the JSP sites, both have a basic continuous sample rate of 20 Hz. Both versions of the IDA DAS have a six-pole anti-aliasing filter with a corner frequency of 5 Hz. Thus the system response is flat to ground velocity between 2.7 mHz and 5 Hz. Below 2.7 mHz, the STS-1 response is flat to ground acceleration.

The IDA MK4 DAS is deployed at stations ARU, GAR, KIV, and OBN, which were installed in 1988. The MK4 was specifically designed to match export control restrictions to the USSR that were in effect in 1988. A major difference between the MK4 and the other data acquisition systems in the IDA family is in the recording medium, which is low-density (1600 bpi) 9-track tape. Export conditions to the USSR changed dramatically between 1988 and 1990, such that the data loggers used at other IDA stations could be exported without restriction to the USSR. The IDA MK6a DAS, which is installed at AAK and TLY, records on digital audio tape medium (DAT), which has a capacity of 1.2 Gigabytes per tape cartridge. Another difference between the IDA MK4 and MK6a DAS is that the MK6a can incorporate data streams from auxiliary sensors; at AAK and TLY, Teledyne-Geotech GS-13 high-frequency seismometers are used, recording in triggered mode with a sample rate of 200 Hz.

Timing for both DAS systems is provided by the Omega broadcast system. However, the way the Omega time is used by the DAS differs between the MK4 and MK6a. In the MK4 system, the sample rate is locked to the external (Omega) time. Thus, as long as the station clock maintains its lock to Omega time, the DAS samples at exactly 20.0000 Hz, to the precision of the Omega oscillator. However, periods of unlock are observed at every station, controlled by such things as atmospheric conditions, the location of the station relative to Omega broadcast sites, and local morphology of the recording sites (e.g., clear horizon vs. steep canyon). When the MK4 loses Omega lock, control of the sample rate falls to the internal oscillator of the MK4 DAS; this oscillator may drift slightly relative to the design sample rate of 20 Hz. If the station has been running on the internal oscillator for a substantial period of time, a *time tear* or apparent discontinuity can occur when Omega lock is reestablished and control of the sample rate reverts to the Omega oscillator. This phenomenon caused Project IDA to decide to decouple the sample rate from the Omega oscillator in later versions of the DAS. Thus in the MK6a, the sample rate is always controlled by the internal oscillator of the DAS. Omega time is recorded and is used to tie internal time back to UTC. All oscillators drift due to aging of the crystal and seasonal variation. Drifts in the internal oscillators in the MK6a systems have been tracked for more than one year at 6 IRIS/IDA stations. A typical value of the deviation of the MK6a oscillators from 20 Hz is on the order of 1×10^{-5}. Note that this does not imply a timing error, because Omega time provides a 'time tag' for the DAS.

3. Site Description: AAK and TLY

Station AAK, Ala-Archa, Kirghizia, is located at 42.639°N, 74.494°E, elevation 1645 meters, approximately 25 km south of the city of Bishkek (formerly Frunze) in mountainous terrain. The AAK station is located in a national park, approximately a 45 minute drive from Bishkek. The site is located approximately 3 miles up a gorge or canyon, accessible by a paved road upon which there is moderate tourist traffic. The gorge is subject to high winds and dynamic weather. The Ala-Archa river, which is approximately 15 meters wide and can show white water during periods of precipitation and runoff, runs through the gorge. The seismometers are situated in a U-shaped horizontal tunnel, approximately one hundred meters long, excavated in the side of the mountain. The entrance to the tunnel is approximately 30 meters above the river. The instrument room is a small chamber off the main tunnel, approximately 75 meters into the tunnel. The temperature inside the chamber is 9.8°C, with an annual variation of less than .25°C. The tunnel is dry. Two steel doors at the tunnel entrance, 5 meters apart, provide isolation from the outdoors; a third door isolates the IDA instrument chamber from the tunnel. The recording building at AAK is located across the river from the tunnel. Signal is digitized in the instrument chamber, and reaches the recording equipment via a 960-m long uplink cable housed mainly in a buried conduit, but crossing the river in a pipe laid across a small bridge. The station is locally maintained by the Kirghiz Institute of Seismology. AAK officially began operation on October 31, 1990 (Julian day 304).

Station TLY, Talaya, Siberia, is located at 51.681°N, 103.644°E, elevation 579 meters, just west of Lake Baikal approximately 120 km from the city of Irkutsk near the villages of Kultuk and Slyudyanka. The station is located up a wooded canyon in a scientific complex, accessible by a dirt road. There is little traffic in the complex, although workers live on site. The seismometers are located approximately 65 meters into a horizontal tunnel excavated in rock. Unlike the AAK tunnel, the TLY tunnel is subject to standing and dripping water. Two steel doors, about 3 m apart, isolate the tunnel from the outdoors; the tunnel temperature is approximately 8°C, with an annual variation of less than .25°C. A free-flowing creek, approximately 2 m wide, separates the tunnel from the recording building. The length of the uplink cable between the instruments and recording equipment is 185 m. The area around the recording building and tunnel entrance is heavily wooded. The station is locally maintained by the staff of the seismological observatory in Irkutsk. TLY officially began operation on October 24, 1990 (Julian day 297).

4. Operational History: AAK and TLY

Since their installation, AAK and TLY have both been subject to operational problems that required site visits and equipment replacement. Data users should be aware of what periods were affected. These are summarized (to mid-1991) below.

Timing at TLY. Reception of the Omega time signal is very poor at TLY. This station also experienced hardware problems with the Kinemetrics Omega receiver and clock, resulting in a long period of clock unlock between 1990:303 through 1991:136, when the Omega clock was replaced. The sample rate of the DAS is controlled by its own internal oscillator, which drifts at some known, small rate. Thus, even if the Omega time stamp is absent for a long period, the timing history should in principle be reconstructible. However, other DAS hardware failures compounded the timing problem, and without the Omega time stamp, many periods cannot be reconstructed. Teleseismic arrival times show that the time at TLY can be uncertain by up to 25 s for some (but not all) of the data recorded between 1990:340 and 1991:135. We are still investigating how many of the timing errors can be recovered. The Omega clock and DAS unit were replaced on 1991:135. Since this time, time quality at the station should be normal.
High-Frequency Channels at TLY. There was an initial problem at TLY that prohibited recording of the high-frequency sensors. This was corrected when the DAS was replaced on 1991:135. There is no high-frequency data from TLY for the period 1990:297 - 1991:135.
Horizontal Broadband Data at TLY. During the time period between 1990:331 through 1991:135, no data are available from the broadband horizontal seismometers at TLY. An error in the software configuration table, possibly due to incorrect operator intervention, irrecoverably corrupted the high-gain N/S data stream. This problem was corrected by a site visit in May 1991. Thus, vertical-component VBB data only is available from TLY for the period 1990:331 - 1991:135.
Horizontal Broadband Data at AAK. The N/S STS-1 broadband seismometer apparently was damaged in transport, resulting in an impaired and non-reconstructable instrument response at low frequencies. The seismometer was replaced on 1991:108. Thus, vertical-component VBB data only is available from AAK for the period of 1990:304 - 1991:107.
High-Frequency Channels at AAK. The vertical seismometer was improperly connected during installation, such that it was not contributing to the trigger algorithm.
E/W Broadband Electronics at AAK. Beginning about 1991:207, anomalously large noise levels were noted on the E/W component broadband channel for frequencies greater than .2 Hz. During a field trip to the station in August 1991, IDA personnel noted that mice had gained access to the box housing the feedback electronics for the E/W STS-1 sensor; the box was resealed. The period subject to increased E/W VBB noise due to mice visitation is 1991:207 - 1991:231.

5. Broadband Noise Performance at AAK and TLY

5.1 Method. Average ambient noise spectra were calculated following the method outlined in Given, 1990. A period of approximately one week was chosen for each station: for AAK, from 91:109 to 91:115; for TLY, from 91:144 to 91:149. In both cases, these time periods are shortly after IDA personnel made site visits to correct some operational problems. Times series were visually inspected to eliminate earthquakes, but otherwise no special care was taken to ensure unrepresentatively quiet noise levels. In general, the 'night' noise samples were taken between 00h-03h local time, and 'day' noise samples were taken between 12h-14h local time. A minimum of 5 time periods taken over the week was used to form the station average. For each time period, power spectral estimates were calculated by section averaging, using 8 sections of 500 s length, with a 50% overlap, where a Hann taper was applied to each section. The 95% confidence level of the spectral estimates are within -2.2 dB and +3.0 dB of the calculated value at each frequency. The three-component, night-averaged noise levels are shown for AAK and TLY in Figures 3 and 4. Day-averaged noise levels are shown in Figures 5 and 6, and the difference between day-averaged and night-averaged noise levels are shown in Figure 7. The IDA broadband channels have a low-pass, anti-aliasing filter with a corner frequency of 5 Hz; this filter response has not been removed from the ground noise spectra, explaining the apparent decrease in noise levels above 5 Hz.

5.2 Discussion. Broadband ambient noise levels generally fall within the range expected based on the noise study of Given, 1990, where the IDA JSP sites ARU, GAR, KIV, and OBN were evaluated. The AAK noise profile above the microseism frequency (about .2 Hz) is very similar to that observed at GAR. This is not surprising, because both stations are in isolated areas in the interior of the continent (GAR and AAK are within 5° of each other), and both deployments are in quiet, isolated rock tunnels. The noise levels above 1 Hz are almost equal, although the AAK sample shows slightly lower noise (6-10 dB) than GAR on the vertical component between 2-3 Hz. Horizontal noise levels below .05 Hz (20 s) appear to be lower at AAK than at GAR, although lower frequency vertical noise is comparable.

The night-averaged TLY noise profile is similar to AAK at frequencies between .01-.4 Hz, although TLY is somewhat quieter than AAK at the lower frequencies (.01-.04 Hz) and at the microseism peak. TLY appears to be the IDA JSP site where the low-frequency horizontal noise levels most closely match the vertical, which is a characteristic of a vault which is well isolated from barometric changes and tilts. Above .4 Hz, TLY noise begins to increase over AAK noise. By 2 Hz, it is higher than AAK noise by almost 20 dB. From 1-3 Hz, TLY noise is roughly at the level of -140 dB relative to $(1\ m/s^2)^2/Hz$, very similar to night-averaged noise observed at KIV, and approximately 15-20 dB lower than night-averaged noise at OBN (Given, 1990). In terms of night-averaged noise levels above 1 Hz, the IDA JSP sites can be ordered from lowest noise to highest noise as follows: AAK-GAR (about equal), ARU, KIV-TLY (about equal), and OBN. The increase in day over night noise can change this order during daytime hours (see following paragraph). The reader is reminded that, although care has been taken to acquire a good estimate of average noise levels at each station, these conclusions are based on noise samples that are limited to discrete periods in time and may not always reflect noise levels at other times.

The difference in day-averaged and night-averaged noise levels at AAK and TLY (Figure 7) is also similar to that observed by Given (1990) for the other IDA JSP sites. Night and day differences are usually significant only above 1 Hz, and the degree depends on two factors; most importantly, the isolation of the station from cultural noise, and secondly, the soundness of the vault. AAK shows a small increase in day-averaged noise levels over night-averaged levels of 6-7 dB peaked at 2-3 Hz. This is about the magnitude of daytime increase seen at GAR, and lower than that observed at ARU and KIV. TLY appears to be unique among the IDA JSP sites in showing *no* increase in day over night noise above 1 Hz. The IDA JSP sites showing the least to the most increase of daytime over nighttime noise levels can then be ordered as follows: TLY, AAK-GAR (about equal), OBN, KIV, and ARU. The cause of the positive difference at AAK below .1 Hz in Figure 7 is not known.

6. Conclusions from AAK and TLY Triggered Channels

Triggered recording of Teledyne Geotech GS-13 seismometers at 200 Hz allows the evaluation of ambient ground noise from 1 Hz to 80 Hz by using data recorded in the pre-trigger buffer, typically of 10 s length. Rigorous averages have not yet been made, but a small sample of data shows that ground noise at both stations, in terms of acceleration units, is generally constant at -150 dB to -140 dB relative to $(1\ m/s^2)^2/Hz$.These are comparable to noise levels found in 100 m deep borehole deployments of the Teledyne Geotech 54100 high-frequency seismometer at ARU, KIV, and CHS (near GAR) using a different data acquisition system (Given, 1990; Berger et al, 1988); they are about 20 dB lower than high-frequency noise levels at OBN. Thus corroborates the conclusion of Given (1990) with two more stations: at quiet tunnel sites, surface instruments can be nearly as quiet as borehole deployments. Station averaged high-frequency noise levels at AAK and TLY that could be used to infer the detection thresholds at these stations remain to be computed.

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8. References

Berger, J., H.K. Eissler, F.L. Vernon, I.L. Nersesov, M.B. Gokhberg, O.A. Stolyrov, and N.T. Tarasov, Studies of high-frequency seismic noise in Eastern Kazakhstan, *Bull. Seismol. Soc. Am.* 78, 1744-1758, 1988.

Given, H.K., Variations in broadband noise at IRIS/IDA stations in the USSR with implications for event detection, *Bull. Seismol. Soc. Am. 80*, 2072-2088, 1990.

9. Figure Captions

Figure 1. Map of operational stations in the global IDA broadband seismic network, as of 12/31/91.

Figure 2. Amplitude response versus period of the Streckeisen STS-1 very-broadband seismometer. (This does not include the response of the IDA DAS.)

Figure 3. Average night time noise power spectra between 100 s and 10 Hz observed at the IDA station AAK (Ala-Archa, Kirghizia). Plots show vertical (top), north (middle), and east (bottom) components. The vertical scale is in decibels relative to acceleration, $(1\ m/s^2)^2/Hz$.

Figure 4. Average night time noise power spectra between 100 s and 10 Hz observed at the IRIS/IDA station TLY (Talaya, Siberia). Plots show vertical (top), north (middle), and east (bottom) components. The vertical scale are in decibels relative to acceleration, $(1\ m/s^2)^2/Hz$.

Figure 5. Day-averaged noise power spectra for AAK.

Figure 6. Day-averaged noise power spectra at TLY.

Figure 7. Difference between day-averaged and night-averaged vertical component noise power spectra at AAK (top) and TLY (bottom). TLY is unique among the IRIS/IDA JSP stations to date in that it shows virtually no increase in day time over night time noise levels, and increase in day over night levels at AAK is low compared to other IRIS/IDA JSP sites. This can be attributed to the relative isolation of these sites from cultural noise, and the quiet conditions of their instrument tunnels.

Global Broadband IDA Network

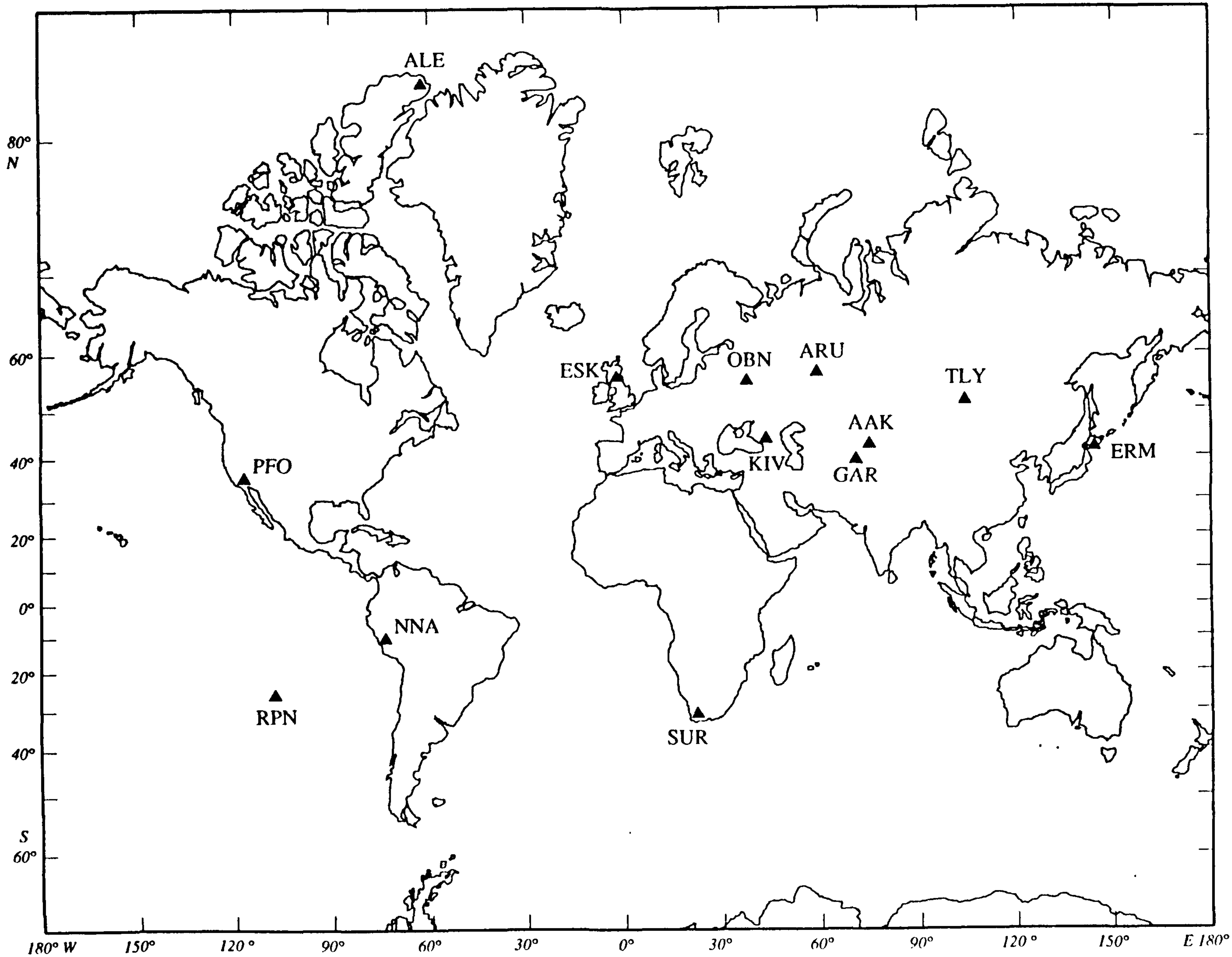
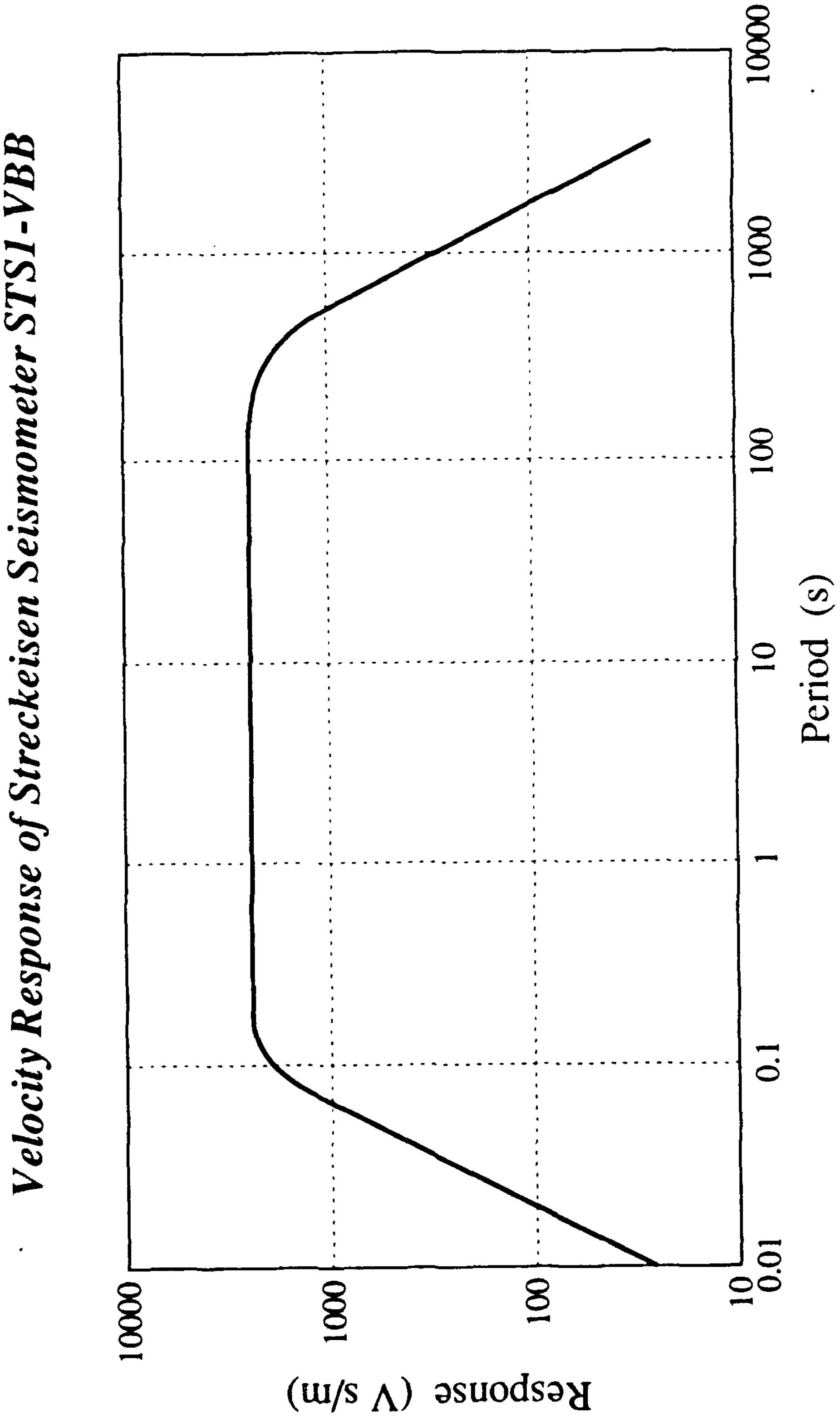


Figure 1



Velocity Response of Streckeisen Seismometer STS1-VBB
Response (V s/m)
10000
1000
100
10
0.01
0.1
1
10
100
1000
10000
Period (s)

Figure 2

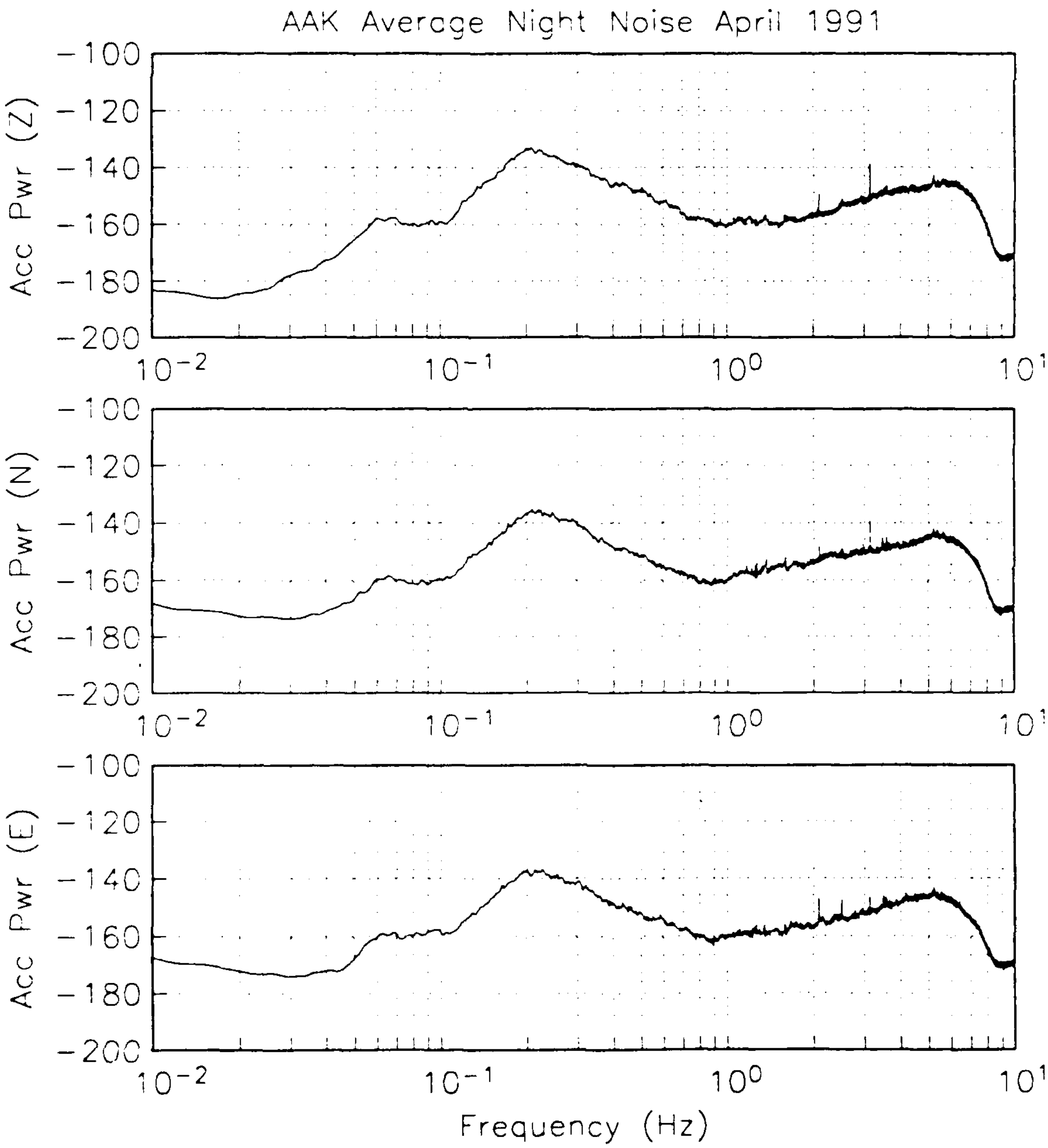

AAK Average Night Noise April 1991
Acc Pwr (Z)
Acc Pwr (N)
Acc Pwr (E)
-100
-120
-140
-160
-180
-200
10^{-2}
10^{-1}
10^{0}
10^{1}
Frequency (Hz)

Figure 3

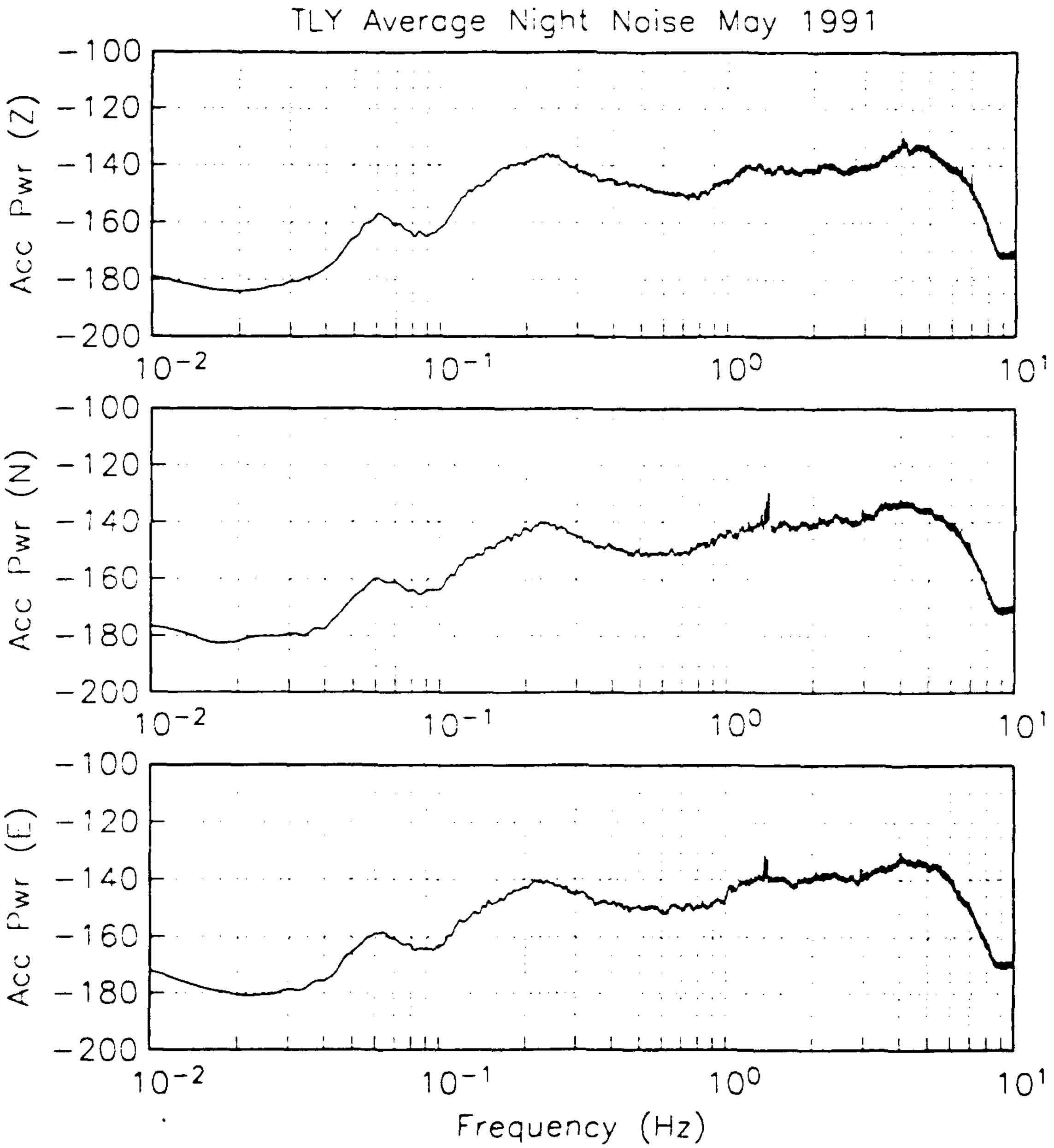

TLY Average Night Noise May 1991
Acc Pwr (Z)
Acc Pwr (N)
Acc Pwr (E)
-100
-120
-140
-160
-180
-200
10^{-2}
10^{-1}
10^{0}
10^{1}
Frequency (Hz)

Figure 4

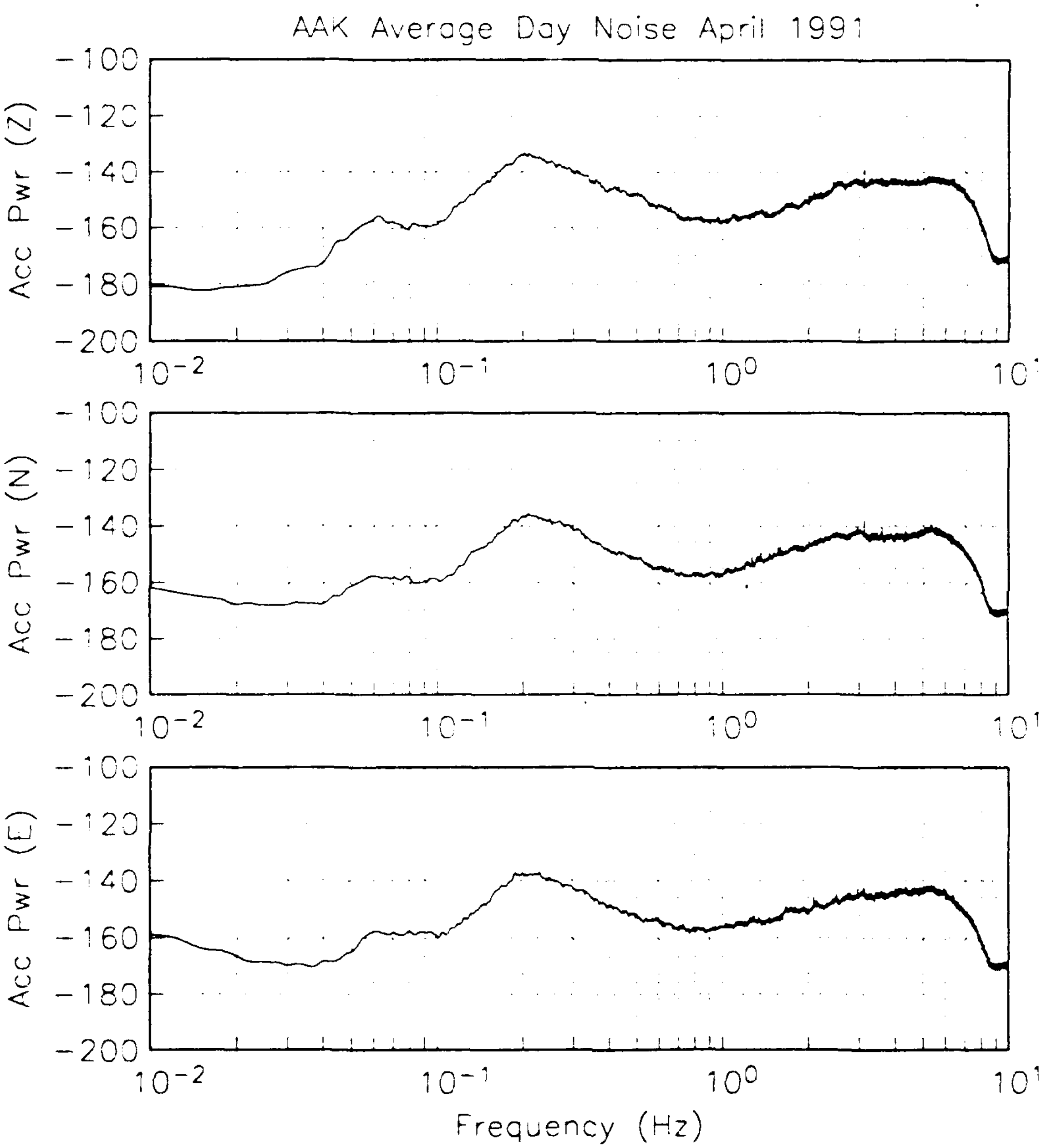
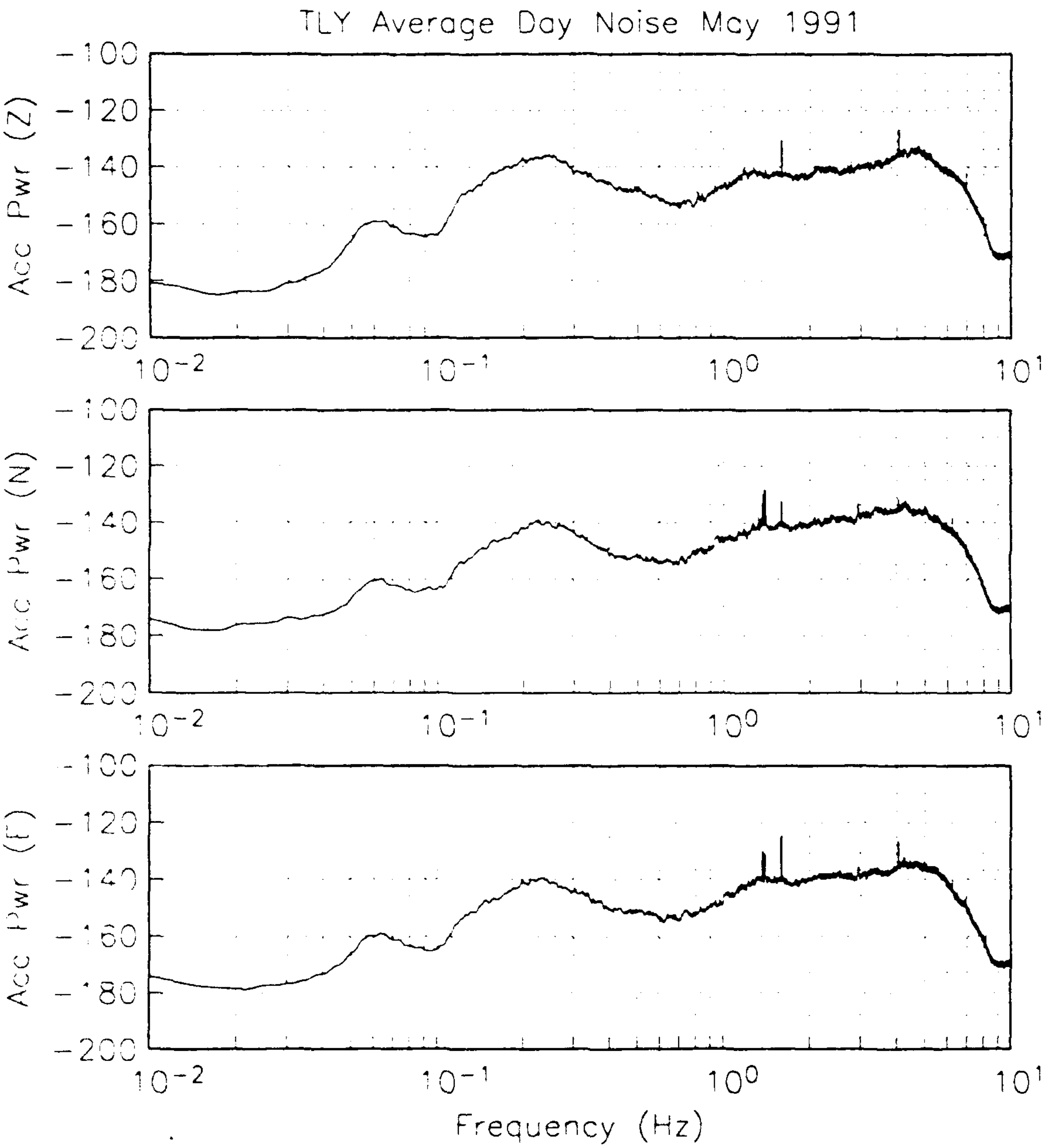

AAK Average Day Noise April 1991
Acc Pwr (Z)
Acc Pwr (N)
Acc Pwr (E)
-100
-120
-140
-160
-180
-200
10^{-2}
10^{-1}
10^{0}
10^{1}
Frequency (Hz)

Figure 5



TLY Average Day Noise May 1991
Acc Pwr (Z)
Acc Pwr (N)
Acc Pwr (E)
-100
-120
-140
-160
-180
-200
10^{-2}
10^{-1}
10^{0}
10^{1}
Frequency (Hz)

Figure 6

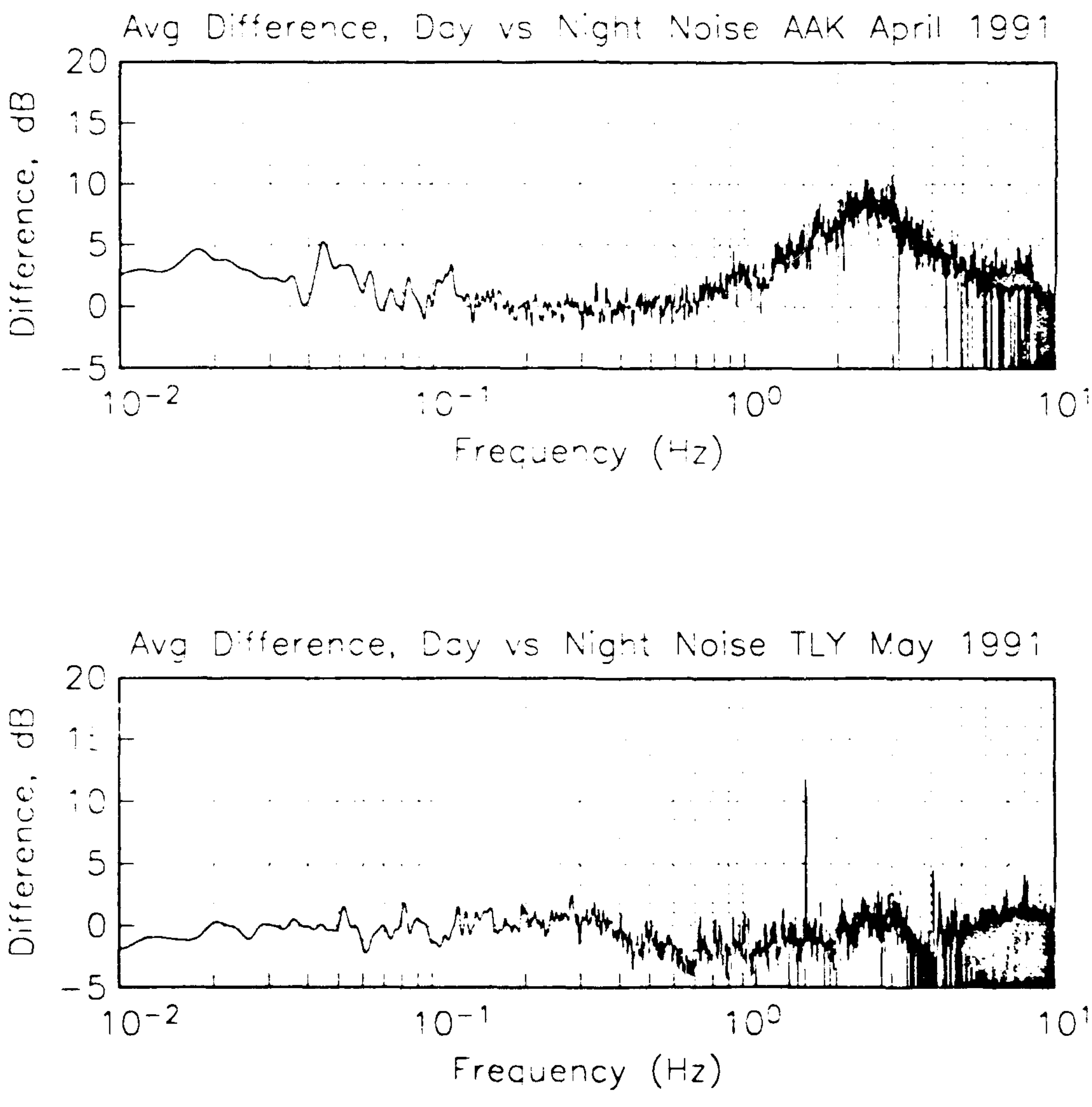

Avg Difference, Day vs Night Noise AAK April 1991
Difference, dB
Frequency (Hz)
Avg Difference, Day vs Night Noise TLY May 1991
Difference, dB
Frequency (Hz)

Figure 7